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Original Communication

Alcohol concentration and carbonation of drinks: The effect on blood alcohol levels

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Abstract

Alcohol absorption and elimination vary considerably amongst individuals, and are subject to influences from a variety of factors. The effects of alcohol concentration and beverage mixer type on the rate of alcohol absorption, in a controlled environment was studied.

21 subjects (12 male, 9 female) consumed a solution containing alcohol, on three separate occasions. The three solutions were, A: Neat vodka (37.5 vol%), B: Vodka mixed with still water (18.75 vol%), C: Vodka mixed with carbonated water (18.75 vol%). The volume of alcohol each subject consumed was determined by Widmark's equation. The alcohol was drunk in a 5 min period following an overnight fast and breath alcohol concentrations were measured over a 4 h period using a breathalyser.

20/21 subjects absorbed the dilute alcohol at a faster rate than the concentrated alcohol. The difference between the absorption rates was found to be significant ($p < 0.001$).

The use of a carbonated mixer had varying effects on the alcohol absorption rate. 14/21 subjects absorbed the alcohol with the carbonated mixer at a faster rate, with 7 subjects showing either no change or a decrease in rate. The mean absorption rate for solution C was 4.39 ± 0.45 (mg/100 ml/min), and the difference between this absorption rate and that with the still mixer ($1.08 + 0.36$) was significant ($p = 0.006$).

1. Introduction

The variability of alcohol absorption and elimination in the human body is well recognised, and has been extensively reported. The blood alcohol concentration (BAC) curve shows the changes in an individual's BAC through time. The shape of the curve is known to follow a basic pattern 2, which is determined by the interaction of the body's absorptive and metabolic processes. Following the consumption of alcohol, an individual's BAC is influenced by a variety of interacting factors, which cause changes in the absorption and elimination rates of the alcohol. Consequently this leads to changes in the shape of the BAC curve.

Alcohol is a small water-soluble molecule, which is absorbed in the gastrointestinal tract by simple passive diffusion. Absorption is most rapid in the small intestine,[1] mainly Due to the large absorptive surface area and extensive blood supply in this region. Some alcohol absorption occurs through the gastric mucosa,[1] but this is thought to have little effect on the BAC. The rate of alcohol absorption varies considerably between individuals and is subject to a significant influence by external factors.

Once absorbed, the alcohol is distributed throughout the body's water content, known as the alcohol distribution volume (ADV). The peak BAC reached is mainly dependant on the amount of alcohol ingested, and the ADV. An increase in the amount of alcohol consumed, or a decrease in the ADV will consequently lead to an increase in the BAC.

The process of alcohol elimination is initiated as soon as alcohol enters the blood stream. The majority of the

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alcohol (90–95%)[2] is metabolised by the liver, with remainder being excreted unchanged in the urine, breath and sweat. Alcohol dehydrogenase (ADH) in the liver oxidises the alcohol to acetaldehyde, which is then metabolised further to acetic acid.[2] Hepatic ADH becomes saturated at low alcohol concentrations leading to a constant elimination rate, which in an average healthy individual is generally accepted to be between 10–25 mg/100 ml/h, with an average of 15–18.6 mg/100 ml/h.[3] However, like alcohol absorption rates, elimination rates are subject to the influence of external factors, although not to as great an extent.

It has long been noted that the concentration of alcohol affects its absorption.[8,10–13] Work done early last century by Miles[13] concluded that low alcohol concentrations (2.75%) were absorbed at a lower rate than higher concentrations (20%), suggesting a linear relationship between the two variables. These studies were later repeated by Lolli and Rubin,[12] who in addition investigated the effect of concentrations of alcohol similar to those found in neat spirits (45%). They hypothesised a "curvilinear" relationship after finding that alcohol concentrations of 45% and 15% were absorbed at a slower rate than alcohol of 30% concentration.[12] It is this theory that is widely accepted today and alcohol absorption is thought to be maximal at concentrations of 10–20%.[2]

High concentrations of alcohol irritate the gastric mucosa, stimulating an increase in mucus secretion.[2,12] This results in a delay in gastric emptying,[12] possibly due to an increase in stomach content volume,[10] caused by the excess mucus. This increases the amount of time the alcohol stays in the stomach, compared to a more dilute solution.[2,8,20] The resulting increase in the duration of contact between the alcohol and the gastric ADH results in an increased gastric metabolism and a lower peak BAC. This is an effect that appears to be compounded by the presence of food in the stomach[8,10,11] Indeed, there is some discrepancy as to whether concentration exerts any effect on alcohol absorption in the fasted state. Two studies[4,8] independently concluded that in the fasted state there is no significant difference between the peak BACs reached at varying concentrations, contradicting earlier findings.[12,13]

The form in which the alcohol is consumed is likely to have an effect on alcohol absorption, other components of alcoholic beverages exerting an effect on gastric emptying rates.[20] The presence of glucose in sweet drinks is known to reduce absorption rates,[7,20] and it is a common belief that the use of a carbonated mixer increases the rate of alcohol absorption, despite there being little evidence to support it.

2. Aims and objectives

The purpose of this study was to investigate, and if possible quantify, (a) any effects that altering the alcohol concentration will have on the rate at which the alcohol is absorbed and (b) assess the effects be of consuming a carbonated and still mixer.

3. Method

This study design was previously approved by the North Manchester Local Research Ethics Committee.

3.1. Subjects

Subjects were recruited following a full explanation of the purpose of the study and the requirements being made of them, using non-technical language. In total 23 subjects (13 male and 10 female) were included in the study aged between 18–27 years, with an average age of 22. All the subjects were healthy and individuals were excluded from the study if they suffered from any significant health problems, or were taking medication that contraindicated the consumption of alcohol. Questioning revealed that all the subjects drank socially, consuming on average 10–20 units a week and none had suffered from any alcohol related problems at any time.

3.2. Study design

Each subject consumed alcohol on three different occasions with a rest period of at least three days, allowing the subject time to recover between phases of the experiment. On each of the three occasions the subjects were given a different solution containing alcohol to drink. No separate control group was used.

The alcohol was consumed following an overnight fast and the subjects were to have abstained from alcohol for the previous 24 h. Each phase of the experiment began between 9 and 10 am and lasted for 4 h.

Before consuming the alcohol the subject's sex and age were noted and the weight and body fat percentage were recorded using a Tanita® body fat monitor. The mean weight of the subjects was 69.5 kg (male 76.3 kg, female 60.5 kg) and the mean body fat percentage was 24.3% (male 18.7%, female 28.9%). In addition an initial BAC was obtained, in order to confirm the subject's alcohol free status. This and all subsequent BAC were estimated from a breath sample obtained using a Lion Alcometer S-D2, which had been previously validated. All BACs were recorded in mg/100 ml.

The alcohol used was Smirnoff vodka (Diageo plc, London), (37.5% vol). The amount of alcohol given to each subject was determined, according to the individual's body weight, using Widmark's equation.[28] The purpose of this was to ensure the subject's BAC did not rise above a safety level of 100 mg/100 ml. Males were given 1.77 ml/kg, (1.4 g/kg) and females 1.33 ml/kg (1.1 g/kg). The amount of vodka given to each subject ranged between 73 ml–167 ml, with an average volume of 111 ml (males 135 ml, females 81 ml). Each subject was given the same amount of vodka in each phase of the experiment, and on two

occasions equal amounts of water were added, diluting the alcohol to half strength.

The three solutions given were:

A Neat vodka (37.5 vol%)
B Vodka diluted with water (18.75 vol%)
C Vodka diluted with carbonated water (18.75 vol%)

The solution that each person started with was randomised, as was the order in which they participated in each phase of the experiment.

The subjects were allowed 5 min to consume the alcohol solution, the start of which was considered to be 0 min. Individuals then thoroughly rinsed their mouths using water. Breath samples were obtained every 5 min over the first 90 min, and then every 15 min up until 4 h, or until a subject recorded two subsequent readings where the alcohol level was undetectable. The first reading taken after the subject rinsed their mouth at 5 min was discarded due to possible contamination. During the experiment the subjects were not allowed to eat, drink or smoke.

Each run of the study was conducted under the same conditions. After consumption of the alcohol, individuals were allowed to partake in quiet activities, such as watching television.

3.3. Data analysis

Each subject's alcohol absorption and elimination curve was plotted. The rate of absorption was calculated by dividing the maximum BAC reached, by the time taken to reach this peak. The peak BAC was considered to be the level at which the BAC first stopped rising.

The mean and standard deviation of the rates of absorption were calculated for groups A, B and C. A paired T test was used to compare the differences in rate between the three groups. For all statistical tests a significance level of 95%, ($p \leqslant 0.05$), was used. Groups A and B were compared, to determine the effect of alcohol concentration, and groups B and C were compared, to determine the effect of carbonation. No comparison was made between groups A and C, as two variables-concentration, and the use of a carbonated mixer, differed between the groups.

4. Results

Of the 23 subjects, 2 individuals (1 male and 1 female) did not complete all three phases of the experiment and so have been excluded from the analysis.

The BACs obtained for all three of the alcohol containing solutions were plotted against time for each subject, an example of which is shown in Fig. 1. The rate of absorption (displayed in mg/100 ml/min) was calculated using the method described in Section 3.3 and statistical analysis was carried out on the results obtained. A summary of the data collected is displayed in Table 1.

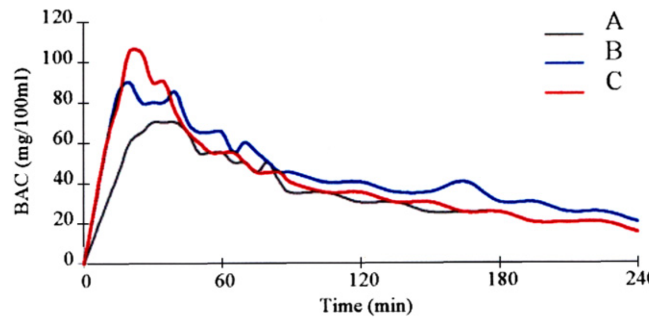

Fig. 1. Sample BAC curve.

Table 1
Rates of absorption for solutions

Subject	Gender	Rate of absorption (mg/100 ml/min)		
		Solution A	Solution B	Solution C
1	M	1.30	2.00	2.00
2	M	3.00	4.00	4.00
3	M	2.33	4.50	5.25
4	M	1.44	2.33	1.63
5	F	2.40	2.33	2.40
6	M	1.40	2.83	4.50
7	F	2.17	3.00	3.00
8	F	3.33	4.75	9.50
9	F	2.00	5.00	7.50
10	M	1.71	3.25	5.00
11	F	1.33	2.17	1.88
12	M	2.60	3.75	7.00
13	M	2.80	3.25	4.67
14	M	2.00	3.20	4.67
15	F	1.33	2.80	3.75
16	M	1.86	3.50	1.86
17	M	2.25	3.00	4.00
18	F	1.67	4.00	6.50
19	F	2.17	4.00	2.60
20	F	1.57	2.75	5.00
21	M	2.29	4.00	5.50
Mean		2.05	3.35	4.60
95% CI		1.80–2.29	2.99–3.72	3.62–5.509

A – Neat Alcohol (37.5 vol%).
B – Alcohol diluted with water (18.75 vol%).
C – Alcohol diluted with carbonated water (18.75 vol%).
NB: All means have been calculated from the original data not the rounded data displayed above.

The more concentrated solution A (37.5 vol%) was absorbed at a slower rate than solution B (18.75 vol%) in all subjects with only one exception. This difference is reflected in the mean absorption rates for solutions A and B as shown in Fig. 2 and Table 1.

The difference in the absorption rate between solutions A and B for any given subject ranges between a decrease of 0.07 to an increase of 3.00, with a mean difference of 1.30, (95% CI: 1.00–1.62). This difference was found to be significant on statistical analysis using a paired t-test ($p < 0.001$), suggesting that the concentration of the alcohol ingested has a significant effect on the rate at which the alcohol is absorbed.

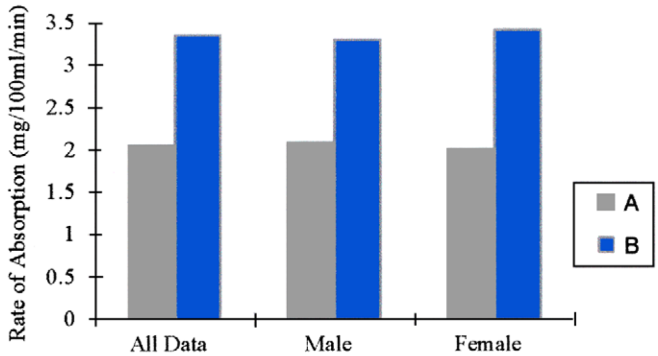

Fig. 2. Comparison of mean absorption rates for alcohol solutions A and B.

Table 2
Absorption rates (mg/100 ml/min) for solutions A and B when divided by gender

		Range of absorption rats	Mean	95% CI
Solution A	Male	1.30–3.00	2.08	1.77–2.40
	Female	1.33–3.33	2.00	1.59–2.41
Solution B	Male	2.00–4.50	3.30	2.90–3.71
	Female	2.33–5.00	3.42	2.74–4.10

Table 3
Difference in rates of absorption (mg/100 ml/min) between solutions A and B, divided by gender

	Range of B–A absorption rates	Mean	95% CI	Significance
Male	0.70–2.17 (1.47)	1.22	0.90–1.53	$p < 0.001$
Female	−0.07–3.00 (3.07)	1.43	0.73–2.11	$p = 0.001$

When the data is divided by gender a similar pattern is noted as to when it is analysed collectively (Fig. 2). Only a minimal difference is noted between the mean rates of absorption recorded for males and females (Table 2). Implying that gender has no significant effect on the absorption rates. The difference between the absorption rates shown when all the data was collectively analysed is still significant when divided by gender (Table 3).

The concentration of alcohol ingested appears to exert an effect on the peak BAC reached (Fig. 1). In the majority of subjects (16 of 21), the peak BAC reached with solution A is lower than the peak BAG reached with solution B, a trend which is illustrated by the mean peak BACs reached (Table 4).

The mean peak BAC reached by males is lower than that reached by females with both alcohol solutions.

The difference between the peak BAC's recorded, for each subject, ranges from a decrease of 5 mg/100 ml with solution B to an increase of 45 mg/100 ml with a mean difference in peak BAC of 11.4 mg/100 ml (95% CI: 5.4–17.5), a result which was shown to be significant ($p = 0.001$). A similar pattern is also noted when the data is divided by gender. The mean difference in peak BAC with males being 9.6 mg/100 ml (95% CI: 2.1–17.1) compared to 13.9 mg/100 ml (95% CI: 2.1–25.7) with females. In both cases this difference was found to be significant.

Table 4
Comparison of peak BAC reached in solutions A and B. (All peak BACs are shown in mg/100 ml)

		Range of peak BAC reached	Mean	95% CI
Solution A	All data	50–90 (40)	66.0	61.4–70.5
	Male	60–90 (30)	71.7	66.1–77.2
	Female	50–65 (15)	58.3	54.7–62.0
Solution B	All data	55–105 (50)	77.4	71.7–83.0
	Male	65–105 (40)	81.3	73.8–88.7
	Female	55–95 (40)	72.2	64.4–80.1

No correlation was found between the peak BAC reached and the absorption rate.

The majority (19/21) of subjects reached the peak BAC with solution B in a quicker time than with solution A, a pattern reflected by the mean times recorded (Table 5). The difference in time taken to reach the peak BAC ranges between an increase of 5 min with solution B to a decrease of 20 min, with a mean difference of 10.2 min (95% CI: 7.1–13.3) which was shown to be significant ($p < 0.001$).

A similar pattern in times is noted when the data is divided by gender (Table 5), only a marginal difference being seen between males and females. The difference in times still being significant when considered separately.

The use of a carbonated mixer (solution C) compared to a still one (solution B) was found, in the majority of cases (18/21) to affect the absorption rate of the alcohol. However, of the individuals that were affected it was not consistent as to whether the change in absorption rate was an increase or a decrease when solution C was consumed (Table 6).

Table 5
Comparison of times taken (minutes) to reach the peak BAC with solutions A and B

		Range of time taken to reach peak BAC	Mean	95% CI
Solution A	All data	15–50 (35)	34.3	30.5–38.1
	Male	25–50 (25)	36.3	31.4–41.1
	Female	15–45 (30)	31.7	25.6–37.8
Solution B	All data	15–35 (20)	24.0	21.7–26.4
	Male	20–35 (15)	25.4	22.4–28.5
	Female	15–30 (15)	22.2	18.9–25.5

Table 6
Effect of type of mixer on the nature of the difference in alcohol absorption rates

	Increase with solution C	No change	Decrease with solution C
Male	8	2	2
Female	6	1	2
All data	14	3	4

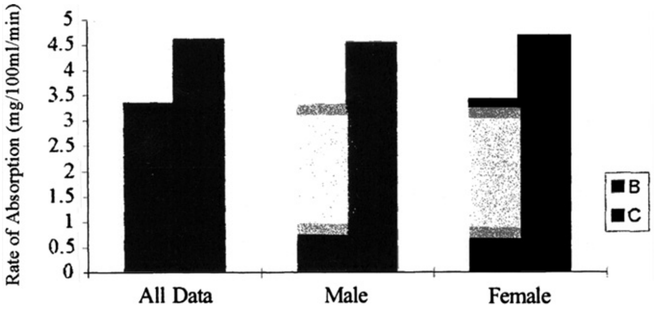

Fig. 3. Comparison of mean absorption rates for alcohol solutions B and C.

The mean absorption rates for solutions B (3.35, 95% CI: 2.99–3.72) and C (4.60, 95% CI: 3.62–5.59), illustrated in Fig. 3, suggest that alcohol mixed with a carbonated mixer is absorbed at a faster rate than alcohol mixed with a still mixer. However, this is misleading as the difference between the rates of absorption varied greatly between individuals, ranging from a decrease of 1.64 to an increase of 4.75. Only two thirds of the subjects tested recorded a faster rate of absorption when consuming alcohol with a carbonated mixer compared to a still one.

The difference in absorption rates between solutions B and C was shown to be significant on statistical analysis with a paired t-test ($p = 0.007$), however, the nature of this difference is unclear.

No significant difference was noted in the mean rates of absorption recorded for males and females (Fig. 3, Table 7). A similar pattern was noted between the difference in absorption rates for solutions B and C when the data was divided by gender (Table 8). However, when the data is analysed in two groups, the difference in absorption rates between solutions B and C is no longer significant.

A difference was noted between the peak BAC reached by solutions B and C. However, this difference is minimal and is likely to be insignificant. The peak BAC reached when solution C was ingested ranged from 60–120 mg/100 ml, with a mean peak of 79.5 mg/100 ml (95% CI: 72.3–86.7), which compares to a range of 50–90 mg/100 ml and a mean value of 77.4 mg/100 ml (95% CI: 71.7–83.0) with solution B. The average difference between the peak BAC reached being 2.1 mg/100 ml However, as with the absorption rates, it was not constant whether the difference between the peak BAC was an increase or a decrease, as only 13 of the 21 subjects recorded an increase in BAC with solution C.

Table 7
Absorption rates (mg/100 ml/min) for solutions B and C when divided by gender

		Range of absorption rate	Mean	95% CI
Solution B	Males	2.00–4.50	3.30	2.90–3.71
	Females	2.33–5.00	3.42	2.74–4.10
Solution C	Males	1.63–9.00	4.55	3.37–5.76
	Females	1.88–9.50	4.68	2.96–6.70

Table 8
Difference in absorption rates between solutions B and C

	Range	Mean	95% CI	Significance
All Data	−1.64–4.75	1.25	0.38–2.12	$p = 0.007$
Males	−1.64–3.25	1.25	−0.28–2.52	$p = 0.054$ (NS)
Females	−1.4–4.75	1.25	−0.20–2.72	$p = 0.082$ (NS)

There was no association between a subject recording a decreased rate of absorption and a decrease in peak BAC. The gender difference in peak BAC noticed with solutions A and B was also present with solution C with males recording a higher average BAC (84.2 mg/100 ml, 95% CI: 73.0–95.3) than females (73.3 mg/100 ml, 95% CI: 66.8–79.9).

There was no significant difference between the time taken for the peak BAC to be reached between solutions B and C. The average difference between the time taken for the two solutions being 2.62 min.

5. Discussion

Alcohol absorption and elimination is susceptible to the effects of many factors. The presence of food[4–11] including the timing,[10] quantity and composition,[4,7,9] of the meal, the type[10] and concentration[8,11–13] of alcohol ingested, individual variation[6,14–16] gender,[4,14,17–19] and factors affecting gastric emptying[7,20] have all been demonstrated to have an effect on BAC.

The stomach plays an important role in determining the BAC. Following oral ingestion the presence of alcohol in the small intestine is controlled by the rate of gastric emptying. This has been considered by some to be the most significant factor in controlling the rate of alcohol absorption,[21] and a direct relationship between the two variables has been hypothesised.[20,22] It therefore follows that factors which alter gastric motility and so affect the rate of gastric emptying, will also affect the rate of alcohol absorption. Gastric motility can be affected by a large number of differing variables, some of which are discussed in more detail later. The presence[4–11] and composition[4,7,9] of food, volume of gastric content,[20] smoking,[23] and drugs, including alcohol,[12,20] have all been shown to exert an influence on gastric emptying.

As well as affecting the rate at which alcohol enters the small intestine, the stomach can have an effect on the amount of alcohol available for absorption. The gastric mucosa contains ADH, similar to that found in the liver. This metabolises the alcohol in the stomach making it unavailable for absorption, a process known as gastric first pass metabolism. It therefore follows that alcohol which stays in the stomach for a longer period of time will undergo a greater first pass metabolism and so will have a lower bioavailability.

The effect of food on the absorption and elimination of alcohol is well recognised.[4–11] The presence of food in the stomach has been shown to decrease alcohol absorption,

reducing the peak BAC by as much as 20–57%,[4–7] depending on the type of food and the nature of the beverage consumed. This reduction is commonly thought to be due to a decrease in the amount of alcohol available for absorption, resulting from an increased oxidation of the alcohol by gastric ADH. This occurs due to the presence of food prolonging the length of time the alcohol is in contact with the gastric mucosa. Which in turn increases the duration and so the effectiveness of the gastric first pass metabolism. However, some studies have shown that more than 95% of the alcohol ingested is absorbed, with or without food present.[24,25]

5.1. Study findings

All the research carried out on the effect of alcohol concentration on alcohol absorption has been done in a controlled manner, and the studies have produced accurate, and statistically valid results. Yet the results of these studies are highly contradictory, disagreeing on whether alcohol concentration affects the rate of absorption in the fasted state. It is thought that in the absence of food in the stomach, small amounts of concentrated alcohol pass through the stomach at much the same rate as larger volumes of more dilute alcohol, allowing little time for gastric metabolism. This allows the peak BAC to be reached in the same amount of time after ingesting the alcohol, and a similar level of BAC is also achieved, regardless of the alcohol concentration ingested. It is possible that the phrase "small amounts of alcohol" provides the key to explaining the discrepancy between the results obtained from previous research and this study.

Lolli and Rubin[12] not only investigated the effects of alcohol concentration on the rate of absorption, but also the effect of alcohol concentration when different volumes of alcohol were consumed. It was concluded that "differences in concentration administered do not affect the rate of absorption when a relatively small amount of alcohol is given".[12] The volumes of alcohol they used when reaching this conclusion are very similar to the volumes employed by other researchers in their studies which have concluded that no significant effect was exerted in a fasted state. However, this is in contrast to the volumes used when a significant difference was observed by Lolli and Rubin, which are similar to the volumes of alcohol solution used in this study.

The difference in alcohol absorption rates seen in this study, varied considerably between individuals reflecting the results of previous studies. The magnitude of the difference in absorption rates between solutions A and B ranged from an individual decrease of 3% to an increase of 111%, with the average difference between the two absorption rates being an increase of 60%. A direct comparison of these results with those of other studies is not possible. This is mainly due to the differing methods used to calculate the rate of absorption, and the variation in prandial state seen. The wide variation in alcohol absorption rates recorded, and the relatively small number of test subjects, means that it has not been possible to establish any definite pattern to the difference in the rate of absorption. The only statistically valid statement that can be made from this evidence is that the concentration of alcohol has been shown to affect the rate of absorption in the fasted state.

Despite the lack of formal research in this area, it is a popular belief that consuming alcohol with a carbonated mixer increases the rate of alcohol absorption. The results of this study indicate that the type of mixer used does exert an effect on the rate of alcohol absorption. However, the results obtained are not necessarily those that would be expected. Two thirds of the subjects tested, absorbed the alcohol and carbonated mixer (solution C) at a faster rate than the alcohol and still mixer (solution B), with the remaining third showed no change in absorption rate between the two solutions or a decreased rate with the carbonated mixer. As no other research in this area has been carried out at the time of writing, no comparison can be made between these results and those of other studies.

Two possibilities exist, that could explain the wide variation in the results obtained. The first is that an error was made at some point in the experimental process, and the results obtained are inaccurate. This would have been considered to be a likely possibility if the number of individuals in this group had been less. However, as every effort was made to reduce sources of error in the experimental process the chances of an error occurring this frequently must be considered to be minimal. The second possibility considered is that an individual reaction to alcohol in the presence of a carbonated mixer differs inter-individually. It is interesting to note that two of the subjects who absorbed the alcohol at a slower rate in the presence of a carbonated mixer are related.

It is this latter hypothesis that has been considered to be the most likely explanation for the results obtained. When ingested, carbonated beverages have been shown to release its gas into the gastric lumen,[29] causing distension of the stomach.[29,30] This distension is thought to increase gastric emptying rates,[29] which would consequently affect alcohol absorption rates. The degree of distension caused is likely to vary between individuals, as is the extent of distension needed to cause gastric emptying. In most cases it is likely that the distension produced is sufficient to alter the rate of gastric emptying. However, it is a possibility that this is not necessarily true for all individuals, resulting in there being no change in absorption rates when a carbonated mixer is used. However, this is only speculation and further research is needed both to confirm the nature of the results and to-formulate an accurate hypothesis.

Although this study has shown a significant link between alcohol concentration and alcohol absorption rates, it was performed in laboratory conditions that do little to mimic normal drinking situations. The results

obtained apply to aqueous alcohol solutions and it is unclear whether they would apply to alcoholic beverages commonly consumed in a social setting. In these cases it is not solely the concentration of alcohol which differs between beverages, but the nature of the mixer used, and the volume consumed, both of which could affect absorption rates. Commonly used mixers, such as lemonade, contain high levels of glucose, which have been shown to affect gastric emptying and therefore alcohol absorption rates. Unless research is undertaken that mimics normal drinking circumstances as much as possible, mistakes could be made in clinical practice. However, it is unlikely that research of this nature would be possible, mainly due to the control of variables necessary to allow the effect of others to be established.

Breath analysis is a commonly used method of obtaining a BAC in the field of practice, and is a technique that is currently deemed accurate to an acceptable level. In these situations a subject is likely to be in the postabsorptive phase of their BAC curve, unlike in this study where BACs were being measured in the absorptive state. There is some evidence to suggest that breath analysis is inaccurate, when used as a measure of BAC, especially in an absorptive state.[31] The blood:breath ratio is thought to be extremely variable during this period, due to differences in venous and arterial BAC, and hand held breathalysers use a fixed ratio of 2100:1. This is believed to lead to a substantial proportion of subjects having their BAC overestimated,[31] and so may question the reliability and validity of these results. However, the degree of uncertainty is unknown, and no large scale studies have been completed on the subject to date. Several researchers have used breath analysis of BAC successfully in the past[4,5,8,10,11,18], and until there is sufficient evidence to the contrary, use of breath sampling can be assumed to be accurate to an acceptable level.

The findings of this study indicate that the concentration of alcohol and the type of beverage ingested affect the absorption rate of the alcohol. This could prove to be of considerable significance to clinical forensic medicine, especially the practice of retrograde extrapolation, used to estimate BAC at an earlier point in time. Previously, little attention was paid to the nature of the drink ingested merely using the amount of alcohol. Using universally accepted estimates of alcohol elimination rates, a breath alcohol reading would be extrapolated backwards to achieve an estimation of the BAC at the time of an incident, which would then be considered with reference to the time of drinking and the amount of alcohol consumed.

This study investigated the effect of alcohol concentration and beverage mixer on the rate of alcohol absorption. It has been concluded that both the variables studied have a significant effect on the rate of alcohol absorption.

These results suggest a varying response to the consumption of a carbonated solution though more research is needed to confirm these observations.

References

1. Elmslie RG, Harvey N. Alcohol absorption rate from different parts of the gut. *Q J Stud Alcohol* 1968;**29**:308–12.
2. Margaret M. Stark, A Physician's Guide to Clinical Forensic Medicine, 1st ed., pp. 199–202.
3. Holford NHG. Clinical pharmacokinetics of ethanol. *Clin Pharmacokinet* 1987;**13**:273–92.
4. Pikaar NA, Wedel M, Hermus RJJ. Influence or several factors on blood alcohol concentrations after drinking alcohol. *Alcohol Alcohol* 1988;**23**:289–97.
5. Watkins RL, Adler EV. The effect of food on alcohol absorption and elimination patterns. *J Forensic Sci* 1993;**38**:285–91.
6. Fraser AG, Rosalkl SB, Gamble GD, Pounder RE. Inter-individual and intra-individud variability of ethanol concentration-time profiles: Comparison of ethanol ingestion before or after and evening meal. *B J Clin Pharmacol* 1995;**40**:387–92.
7. Sedman AJ, Wilkinson PK, Sakmar E, Weidler DJ, Wagner JG. Food effects on absorption and metsibolism of alcohol. *J Stud Alcohol* 1976;**37**:1197–214.
8. Roine RP, Gentry T, Lim RT, Baraona E, Lieber CS. Effect of concentration of ingested ethanol on blood alcohol levels. *Alcohol Exp Clin Res* 1991;**15**:734–8.
9. Rogers J, Smith J, Stamer GA, Whitfield JB. Differing effects of carbohydrate, fat and protein on the rate of elhanol metabolism. *Alcohol Alcohol* 1987;**22**:345–53.
10. Roine RP, Gentry T, Lim RT, Helkkonen E, Salspuro M, Lieber C. Compansonol blood alcohol concentrations after beer and whiskey. *Alcohol Clin Exp Res* 1993;**17**:709–11.
11. Roine R. Interaction of prandial state and beverage concentration on alcohol absorption. *Alcohol Clin Exp Res* 2000;**24**:411–2.
12. Lolli G, Rubin M. The effect of concentration of alcohol on the rate of absorption and the shape of the blood alcohol curve. *Q J Stud Alcohol* 1943;**4**:57–63.
13. Miles WR. The comparative concentrations of alcohol in human blood and urine at intervals after ingestion. *J Pharmacol Exp Ther* 1922;**20**:265–319.
14. Thomasson HR. Gender differences in alcohol metabolism. *Recent Develop Alcohol* 1995;**12**:163–79.
15. Jones AW. Interindividual variations in the disposition and metabolism of ethanol in healthy men. *Alcohol* 1984;**1**:385–91.
16. O'Neill B, Williams AF, Dubowski KM. Variability in blood alcohol concentrations. implications for estimating individual results. *J Stud Alcohol* 1983;**44**:222–30.
17. Arthur MJ, Lee A, Wright R. Sex differences in the metabolism of ethanol and acetaldehyde in normal subjects. *Clin Sci* 1984;**67**:397–401.
18. Marshall AW, Kinstone D, Boss M, Morgan MY. Ethanol elimination in males and females: Relationship to menstrual cycle and body composition. *Hepatology* 1983;**3**:701–6.
19. Frezza M, Di Padoza C, Pozzato G, Terpin M, Baraona E, Lieber CS. High blood alcohol levels in women. The role of decreased gastric alcohol dehydrogenase activity and first-pass metabolism. *New Eng J Med* 1990;**322**:95–9.
20. Holt S. Observations on the relation between alcohol absorption and the rate of gastric emptying. *CMAJ* 1981;**124**:267–72.
21. Cori CF, Villiaume EL, Cori GT. Studies on intestinal absorption II. The absorption of ethyl alcohol. *J Biol Chem* 1930;**87**:19–25.
22. Holt S, Stewart MJ, Adam RD, Heading RC. Alcohol absorption, gastric emptying and a breathalyser. *B J Clin Pharm* 1980;**9**:205–8.
23. Grimes DS, Goddard J. Effect of cigarette smoking on gastric emptying. *BMJ* 1978;**2**:460–1.
24. Southgate HW. The effect of alcohol, under varying conditions of diet, on man and animals, with some observations on the fate of alcohol in the body. *J Biochem* 1925;**19**:737–45.
25. Harger RN, Hulpieu HR. Extent of absorption of alcohol at various intervals after oral administration. *Proc Soc Exp Biol (NY)* 1935;**32**:1247–9.

28. Forrest ARW. The estimation of Widmark's factor. *J Forensic Sci Soc* 1986;**26**:249–52.
29. Ploutz-Snyder L, Foley J, Pkoutz-Snyder R, Kanaley J, Sagendorf K, Meyer R. Gastric gas and fluid emptying assessed by magnetic resonance imaging. *E J Appl Physiol Occup Physiol* 1999;**79**:212–20.
30. Pouderoux P, Freidman N, Shirazi P, Ringlestein JG, Keshavarzian A. Effect of carbonated water on gastric emptying and intragastric meal distribution. *Dig Dis Sci* 1997;**42**:34–9.
31. Simpson G. Accuracy and precision of breath alcohol measurements in the absorptive state. *Clin Chem* 1987;**33**:753–6.